PCT

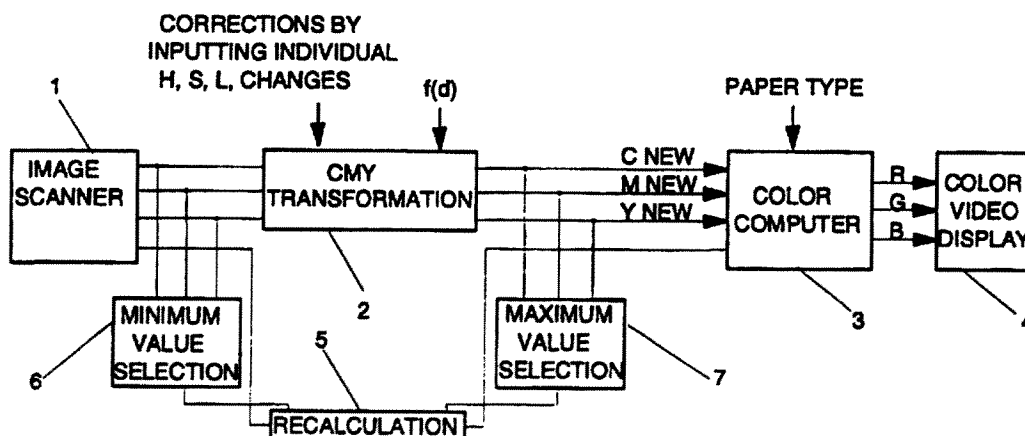| (51) International Patent Classification 6 :		(11) International Publication Number:	**WO 96/08913**
H04N 1/60	A1	(43) International Publication Date:	21 March 1996 (21.03.96)

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(54) Title: BLACK RECALCULATION FOR ARBITRARY HSL CORRECTIONS IN CMY COLOR SPACE

(57) Abstract

A method for defining a new value of K (black) corresponding with a change in CMY components. Original CMYK printing colors are provided. The original CMY printing colors are corrected to create new CMY printing colors. A value of a smallest one of the original CMY colors is sensed. A value of a smallest one of the new CMY colors is sensed. By use of each of these smallest values, the original K printing color value is modified to create a recalculated K printing color value. The recalculated black value corrects for distortion of original gray balance.

BLACK RECALCULATION FOR ARBITRARY HSL CORRECTIONS IN CMY COLOR SPACE

RELATED APPLICATION

5   The present application is related to our copending international patent application, filed this same day, having our internal number 92/846 titled "HSL CORRECTIONS IN CMY COLOR SPACE",

BACKGROUND OF THE INVENTION

10   This patent describes color manipulation for digital image processing in the prepress industry.

As a result of attempts to introduce more intuitive color manipulation, HSL (Hue,
15   Saturation, Luminance) changes are executed in three steps. In the first step, the original image is translated from the printable CMY color space to the HSL (or equivalent) color space, which is unprintable, but which is convenient for calculation. In the second step, the HSL changes are applied according to a binary mask and are executed in the new color space. In the third step, the new
20   image is translated back to the printable color space. The original black remains unchanged in such color manipulation.

$$(CMY)_{original} \Rightarrow \text{color space translation-} \Rightarrow [HSL(\text{or equivalent})]_{original}$$

25   $$[HSL(\text{or equivalent})]_{original} \Rightarrow HSL \text{ change} \Rightarrow [HSL(\text{or equivalent})]_{new}$$

$$[HSL(\text{or equivalent})]_{new} \Rightarrow \text{-color space translation} \Rightarrow (CMY)_{new}$$

In this approach it is difficult to: 1) accomplish quality translations between color
30   spaces; 2) meet precision requirements; 3) decide how to treat unprintable colors; 4) achieve interactive performance; 5) avoid the undesirable effects of binary weighting; and 6) not distort the original gray balance.

SUMMARY OF THE INVENTION

35   It is an object of the invention to solve the above identified problems, and particularly not to distort the original gray balance.

According to the method of the invention, a new value of K (black) is defined
corresponding with a change in CMY components. Original CMYK printing colors
are provided. The original CMY printing colors are corrected to create new CMY
printing colors. A value of the smallest one of the original CMY colors is sensed.

5   A value of a smallest one of the new CMY colors is sensed. By use of each of
these two smallest values, the original K printing color value is modified to create
a recalculated K printing color value.

Color manipulation is simpler and more natural when done by hue, saturation
and luminance adjustments. The restoration of the black balance is intuitively

10   expected. The hue, saturation and luminance changes are executed in one step
without the color space translations. The restoration of gray balance is based on
the original CMYK image combined with the CMY changes applied to it during
the color manipulation.

Hue, saturation, and luminance changes are applied directly to the CMY colors

15   and are executed smoothly in the CMY color space according to a weighted
mask. After the CMY color manipulation, the new black component is created to
restore the gray balance of the original image. The image remains always in the
same printable CMYK color space.

20   All calculations are based on the original CMYK image and are executed on a
pixel by pixel basis with respect to the nonlinear gray line rather than to the color
cube diagonal (the gray line is the absence of color but changing luminance).
The gray line extends nonlinearly through the CMY color space. Both original
and new images are maintained in the printable CMY color space.

25

After the CMY color manipulation, the new black component is created to restore
the gray balance of the original image. The image always remains in the same
printable CMYK color space.

The restoration of the gray balance is based on the original CMYK image

30   combined with the CMY changes applied to it during the color manipulation. The
new black calculation is executed in one step and is performed on a pixel by pixel
basis. Both original and new images remain in the printable CMYK color space.

K treatment for arbitrary CMY changes is provided. The following change,

35   applied directly to CMY colors and executed in the CMY color space during the
color manipulation, is given:

$$(CMY)_{original} \Rightarrow \text{color manipulation} \Rightarrow (CMY)_{new}$$

The new black component is created from the original black combined with the skeleton black gradation functions of the CMY components before and after the color manipulation.

$K_{original} \Rightarrow$ new black creation $\Rightarrow K_{new}$

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1   is a block diagram showing the method of the invention for defining a new value of K corresponding with a change in CMY components;

Figure 2   is an illustration of a CMY color space showing hue change;

Figure 3   is an illustration of a CMY color space showing saturation change; and

Figure 4   is an illustration of a CMY color space showing luminance change.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The K recalculation method according to the invention is most easily understood as shown by the block diagram in Figure 1. An image scanner creates original values $C_{original}$, $M_{original}$, $Y_{original}$, and $K_{original}$. The image scanner 1 creates these color values by scanning an original image. The color values are then input into a CMY transformation 2 where new color values C_{new}, M_{new}, and Y_{new} are created based on HSL changes input into the CMY transformation 2. A masking function f(d) is also input.

The new color values C_{new}, N_{new}, and Y_{new} are then input into color computer 3 which converts these colors to RGB video signals for input to a color video display 4. Paper type can also be input into the color computer. The above was described in greater detail in my copending international patent application, having our internal number 92/846, titled "HSL CORRECTIONS IN CMY COLOR SPACE" and incorporated herein by reference.

According to the present invention, the black value K_{orig} is input into a K recalculation 5. The minimum value selection 6 selects the smallest of the three values C_{orig}, M_{orig}, and Y_{orig}. The minimum value selection 7 also selects the smallest of the new color values C_{new}, M_{new}, and Y_{new}. These two minimum values are then input into the K recalculation 5 which then recalculates the K and outputs K_{recalc}.

The HSL changes and K treatment shall now be described in greater detail.

HUE CHANGE

As shown in Figure 2, each hue change is applied directly to the CMY colors and is executed in the CMY color space 10. The original color rotates in its luminance plane 13 (perpendicular to the color cube diagonal 14) around the intersection of
5   this plane with the gray line 12 (the gray line represents absence of color but increasing luminance):

$$(CMY)_{original} \Rightarrow .\text{hue change} \Rightarrow (CMY)_{new}$$

A maximum desired hue change is described as:

10    $$-180° \leq CHANGE \leq 180°$$

Input data consists of: 1) the image as an array of pixels, with the $(CMY)_{original}$ color components specified for each pixel; and 2) an optional weighting mask as an array of pixels, with a percentage of the maximum desired change specified
15   for each pixel:

$$0 \leq d \leq 100\% \text{ (for a global change d = 100\%)}$$

For each pixel of the image, the following five steps are carried out:

20   1.   Two change coefficients are calculated according to the maximum desired hue change and an arbitrary function of the optional weight:

$$COEFF_1 = \cos[f(d)CHANGE] \text{ and } COEFF_2 = \frac{\sqrt{3}}{3} \sin[f(d)CHANGE]$$

25   2.   The intersection of the color cube diagonal with a luminance plane perpendicular to it is calculated as:

$$D = 1/3(Y_{original} + M_{original} + C_{original})$$

30   3.   The intersection of the gray line with a luminance plane is calculated as the empirically established function of the color cube diagonal intersection with the same plane:

$$Y_{gray} = f_y(D), M_{gray} = f_M(D) \text{ and } C_{gray} = f_c(D)$$

35

    4.   New color components (after the hue change) are calculated as:

$$Y_{new} = COEFF_1 (Y_{original} - Y_{gray}) + COEFF_2 (M_{original} - M_{gray} - C_{original} + C_{gray}) + Y_{gray}$$

$$M_{new} = COEFF_1 (M_{original} - M_{gray}) + COEFF_2 (C_{original} - C_{gray} - Y_{original} + Y_{gray}) + M_{gray}$$

$$C_{new} = COEFF_1 (C_{original} - C_{gray}) + COEFF_2 (Y_{original} - Y_{gray} - M_{original} + M_{gray}) + C_{gray}$$

5. The new color components can be clamped between the color limits of the available CMY color space and/or are subjected to the saturation adjustment which preserves the desired hue and luminance values for $0 \le C_{gray} \le C_{max}$:

$$C_{new,corr} = COEFF (C_{new} - C_{gray}) + C_{gray}$$

$$M_{new,corr} = COEFF (M_{new} - M_{gray}) + M_{gray}$$

$$Y_{new,corr} = COEFF (Y_{new} - Y_{gray}) + Y_{gray}$$

where COEFF is the smallest of:

$$\frac{C_{limit} - C_{gray}}{C_{new} - C_{gray}}, \quad \frac{M_{limit} - M_{gray}}{M_{new} - M_{gray}} \text{ and } \quad \frac{Y_{limit} - Y_{gray}}{Y_{new} - Y_{gray}}$$

where

$$COLOR_{limit} = 0 \quad \text{for } COLOR_{new} < 0$$

$$COLOR_{limit} = COLOR_{max} \quad \text{for } COLOR_{new} > COLOR_{max}$$

$$COLOR_{limit} = COLOR_{new}$$

6. The empirically established skeleton black gradation function for the smallest of the original CMY color components is calculated as:

$$SB_{original.} = f_{skeleton\ black}(\text{smallest of } Y_{original}, M_{original}, C_{original})$$

7. The empirically established skeleton black gradation function for the smallest of the new CMY color components is calculated as:

$$SB_{new} = f_{skeleton\ black}(\text{smallest of } Y_{new,\ corr}, M_{new,corr}, C_{new,\ corr})$$

8. The new black component is calculated as:

$$K_{new} = K_{original} - SB_{original} + SB_{new}$$

SATURATION CHANGE

As shown in Figure 3, each saturation change is applied directly to the CMY colors and is executed in the CMY color space 10. The original color moves along the line 15 which connects this color to the intersection of its luminance
5   plane with the gray line 12. Decreases and increases in saturation are achieved by moving to and from this intersection, respectively:

$$(CMY)_{original} \Rightarrow \text{saturation change} \Rightarrow (CMY)_{new}$$

10   A maximum desired saturation change is described as a percentage of the actual saturation: $0 \leq CHANGE \leq 1$ for saturation decrease and $1 < CHANGE$ for saturation increase. The input data consists of: 1) the image as an array of pixels, with the $(CMY)_{original}$ color components specified for each pixel; and 2) an optional weighting mask as an array of pixels, with a percentage of the maximum desired
15   change specified for each pixel: $0 \leq d \leq 100\%$ (for a global change $d = 100\%$).

For each pixel of the image, the following five steps are carried out:

1.   The change coefficient is calculated according to the maximum desired
20   saturation change and an arbitrary function of the optional weight:

$$COEFF = 1 + f(d)CHANGE$$

2.   The intersection of the color cube diagonal with a luminance plane
25   perpendicular to it is calculated as:

$$D = 1/3(Y_{original} + M_{original} + C_{original})$$

3.   The intersection of the gray line with a luminance plane is calculated as the
30   empirically established function of the color cube diagonal intersection with the same plane:

$$Y_{gray} = f_y(D), M_{gray} = f_M(D) \text{ and } C_{gray} = f_c(D)$$

35   4.   New color components (after the saturation change) are calculated as:

$$Y_{new} = COEFF(Y_{original} - Y_{gray}) + Y_{gray}$$
$$M_{new} = COEFF(M_{original} - M_{gray}) + M_{gray}$$

$$C_{new} = COEFF(C_{original} - C_{gray}) + C_{gray}$$

5. The new color components can be clamped between the color limits of the available CMY color space and/or subjected to the saturation adjustment which preserves the desired hue and luminance values for $0 \leq C_{gray} \leq C_{max}$:

$$C_{new,corr} = COEFF(C_{new} - C_{gray}) + C_{gray}$$
$$M_{new,corr} = COEFF(M_{new} - M_{gray}) + M_{gray}$$
$$Y_{new,corr} = COEFF(Y_{new} - Y_{gray}) + Y_{gray}$$

where COEFF is the smallest of:

$$\frac{C_{lim it} - C_{gray}}{C_{new} - C_{gray}}, \quad \frac{M_{lim it} - M_{gray}}{M_{new} - M_{gray}} \text{ and } \quad \frac{Y_{lim it} - Y_{gray}}{Y_{new} - Y_{gray}}$$

where

$$COLOR_{limit} = 0 \quad \text{for } COLOR_{new} < 0$$
$$COLOR_{limit} = COLOR_{max} \text{ for } COLOR_{new} > COLOR_{max}$$
$$COLOR_{limit} = COLOR_{new}$$

6. The empirically established skeleton black gradation function for the smallest of the new CMY color components is calculated as:

$$SB_{original.} = f_{skeleton\ black}(\text{smallest of } Y_{original}, M_{original}, C_{original})$$

7. The empirically established skeleton black gradation function for the smallest of the new CMY color components is calculated as:

$$SB_{new} = f_{skeleton\ black}(\text{smallest of } Y_{new,\ corr}, M_{new,corr}, C_{new,\ corr})$$

8. The new black component is calculated as:

$$K_{new} = K_{original} - SB_{original} + SB_{new}$$

LUMINANCE CHANGE

As shown in figure 4, each luminance change is applied directly to the CMY colors and is executed in the CMY color space 10. The original color moves along the line 16 which connects this color to the point of minimum luminance on

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the gray line 12. Decreases and increases in luminance are achieved by moving to and from this point, respectively:

$$(CMY)_{original} \Rightarrow luminance\ change \Rightarrow (CMY)_{new}$$

5

A maximum desired luminance change is described as a percentage of the actual luminance: $0 \leq CHANGE \leq 1$ for luminance decrease and $1 < CHANGE$ for luminance increase.

The input data consists of: 1) the image as an array of pixels, with the

10    $(CMY)_{original}$ color components specified for each pixel; and 2) an optional weighting mask as an array of pixels, with a percentage of the maximum desired change specified for each pixel: $0 \leq d \leq 100\%$ (for a global change d = 100%).

For each pixel of the image, the following five steps are carried out:

15

1.   The change coefficient is calculated according to the maximum desired luminance change and an arbitrary function of the optional weight:

$$COEFF = 1 + f(d)\ CHANGE$$

20

2.   The intersection of the color cube diagonal with the largest color luminance plane is calculated as:

$$D_{max} = 1/3(Y_{max} + M_{max} + C_{max})$$

25

3.   The point of minimum luminance on the gray line is described as:

$$Y_{gray,max} = f_y(D_{max}),\ M_{gray,max} = f_M(D_{max})\ and\ C_{gray,max} = f_c(D_{max})$$

30   4.   New color components (after the luminance change) are calculated as:

$$Y_{new} = COEFF(Y_{original} - Y_{gray,\ max}) + Y_{gray,\ max}$$
$$M_{new} = COEFF\ (M_{original} - M_{gray,\ max}) + M_{gray,\ max}$$
$$C_{new} = COEFF(C_{original} - C_{gray,\ max}) + C_{gray,\ max}$$

35

5.   The new color components can be clamped between the color limits of the available CMY color space and/or subjected to the saturation adjustment which preserves the desired hue and luminance values for $0 \leq C_{gray} \leq C_{max}$:

$$C_{new,corr} = COEFF(C_{new} - C_{gray,\,new}) + C_{gray,\,new}$$
$$M_{new,corr} = COEFF(M_{new} - M_{gray,\,new}) + M_{gray,\,new}$$
$$Y_{new,corr} = COEFF(Y_{new} - Y_{gray,\,new}) + Y_{gray,\,new}$$

5   where COEFF is the smallest of:

$$\frac{C_{lim\,it} - C_{gray}}{C_{new} - C_{gray}}, \quad \frac{M_{lim\,it} - M_{gray}}{M_{new} - M_{gray}} \text{ and } \quad \frac{Y_{lim\,it} - Y_{gray}}{Y_{new} - Y_{gray}}$$

where:

10

$$COLOR_{limit} = 0 \quad \text{for } COLOR_{new} < 0$$
$$COLOR_{limit} = COLOR_{max} \quad \text{for } COLOR_{new} > COLOR_{max}$$
$$COLOR_{limit} = COLOR_{new}$$

The intersection of the color cube diagonal with the new color luminance plane is
15   calculated as:

$$D_{new} = 1/3 \, (Y_{new} + M_{new} + C_{new})$$

The intersection of the gray line with the new color luminance plane is calculated
20   as the empirically established function of the color cube diagonal intersection
with the same plane:

$$Y_{gray,new} = f_y \, (D_{new}), \ M_{gray,new} - f_M(D_{new}) \text{ and } C_{gray,new} = f_c \, (D_{new})$$

6.   The empirically established skeleton black gradation function for the
25   smallest of the new CMY color components is calculated as:

$$SB_{original} = f_{skeleton\ black}(\text{smallest of } Y_{original},\, M_{original},\, C_{original})$$

7.   The empirically established skeleton black gradation function for the
30   smallest of the new CMY color components is calculated as:

$$SB_{new} = f_{skeleton\ black}(\text{smallest of } Y_{new,\,corr},\, M_{new,corr},\, C_{new,\,corr})$$

8.   The new black component is calculated as:

35

$$K_{new} = K_{original} - SB_{original} + SB_{new}$$

CREATION OF BLACK COMPONENT

For each of the above hue, saturation and luminance changes, as shown in
Figure 1, the new black component is created from the original black combined
5   with the skeleton black gradation functions of the CMY components before and
after the color manipulation:

$$K_{original} \Rightarrow \text{new black creation} \Rightarrow K_{new}$$

10   Summarizing, the input data consists of the image as an array of pixels, with the
$(CMYK)_{original}$ color components specified for each pixel. For each pixel of the
image, the following three steps are carried out:

1. The empirically established skeleton black gradation function for the
15   smallest of the original CMY color components is calculated as:

$$SB_{original} = f_{skeleton\ black}\ (\text{smallest of } Y_{original}, M_{original}, C_{original})$$

2. The empirically established skeleton black gradation function for the
20   smallest of the new CMY color components is calculated as:

$$SB_{new} = f_{skeleton\ black}\ (\text{smallest of } Y_{new,corr}, M_{new,corr}, C_{new,corr})$$

3. The new black component is calculated as:
25

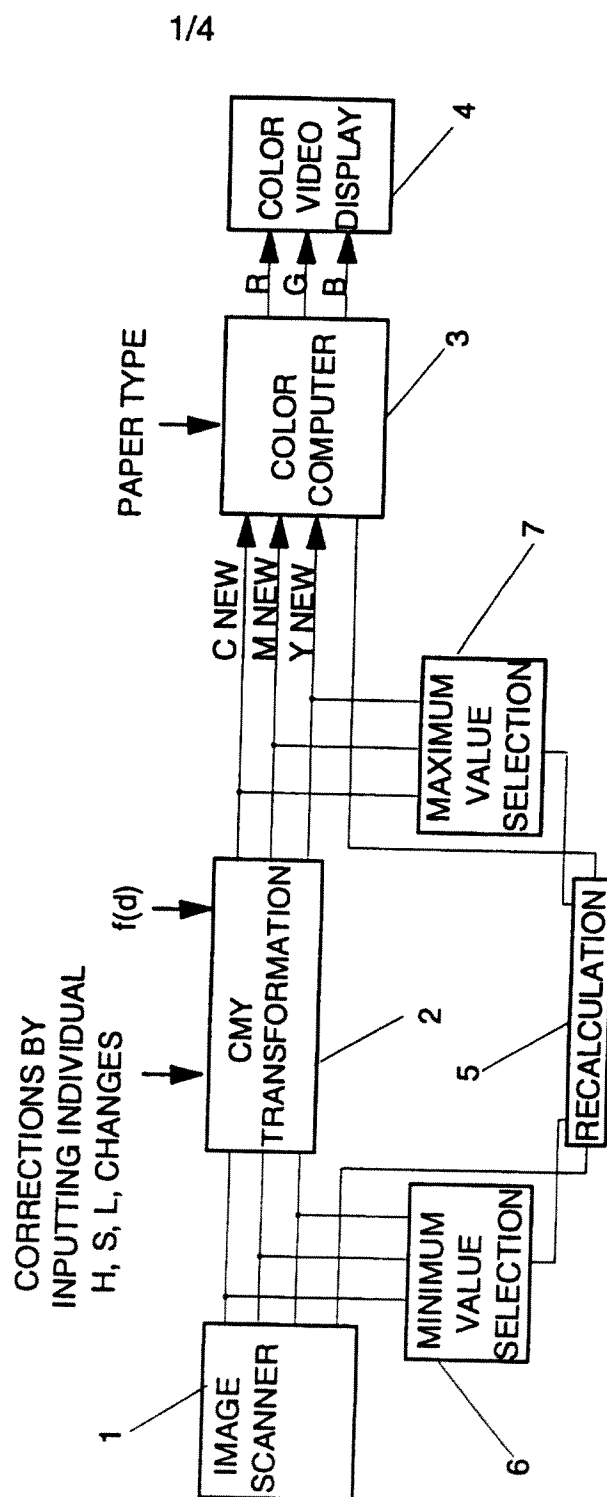$$K_{new} = K_{original} - SB_{original} + SB_{new}$$

This new black value is clamped between $\varnothing$ and some max value. Although
various minor changes and modifications might be proposed by those skilled in
30   the art, it will be understood that we wish to include within the claims of the
patent warranted hereon all such changes and modifications as reasonably come
within our contribution to the art.
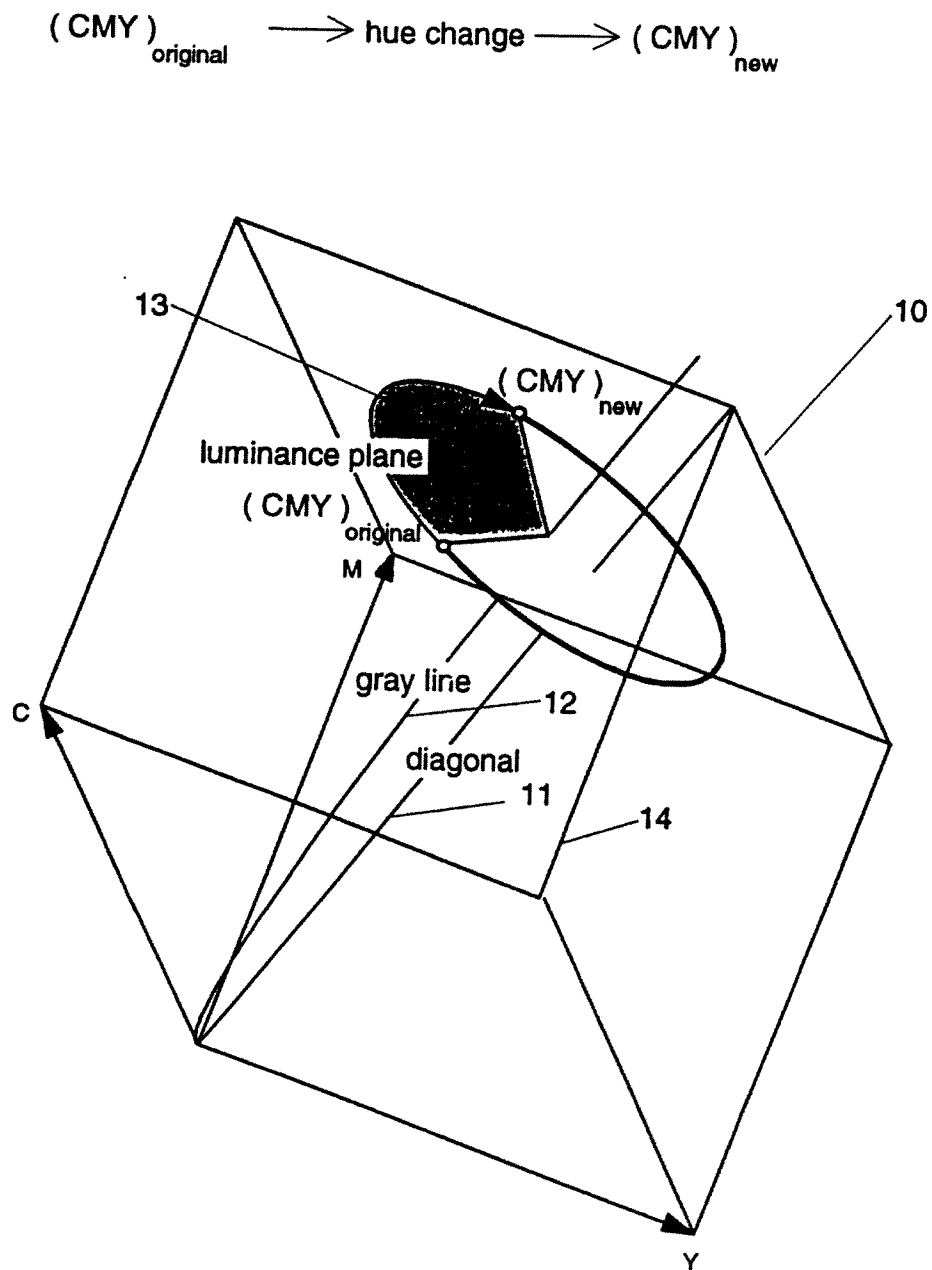
WE CLAIM AS OUR INVENTION:

1. A method for defining a new value of K corresponding with a change in CMY components, comprising the steps of:

    providing original CMYK printing colors where K is a black value;

5   correcting the original CMY printing colors to create new CMY printing colors;

    sensing a value of a smallest one of the original CMY colors;

    sensing a value of a smallest one of the new CMY colors; and

    by use of each of said smallest values, modifying a value of the original

10   black K printing color to create a recalculated black K printing color value.

2. A method according to claim 1 wherein K is modified by:

    first defining a gradation function;

    applying both of the smallest values to the gradation function to obtain first

15   and second function values, respectively; and

    from the original black K value subtracting the first value and adding the second value to obtain said recalculated black K printing color value.

3. A method according to claim 2 including the step of clamping the

20   recalculated black K value between zero and some maximum value.

4. A method according to claim 1 wherein said recalculated black K value corrects for distortion of original gray balance.

25 5. A method according to claim 1 wherein the original CMY printing colors are corrected by inputting HSL changes in a CMY transformation to create said new CMY printing colors.

6. A method according to claim 5 wherein the new CMY printing color values

30   are input to a color computer which then outputs RGB video signals for driving a color video display.

7. A method for defining a new value of K and new values of CMY components corresponding with an HSL change in CMY components,

35   comprising the steps of:

    providing original CMYK printing colors;

    correcting the original CMY printing colors in a CMY transformation by inputting HSL changes in a transformation to create new CMY printing

colors;

sensing a value of a smallest one of the original CMY colors;

sensing a value of a smallest one of the new CMY colors; and

by use of each of said smallest values modifying a value of the original K

5   printing color to create a recalculated K printing color value.

FIG. 1

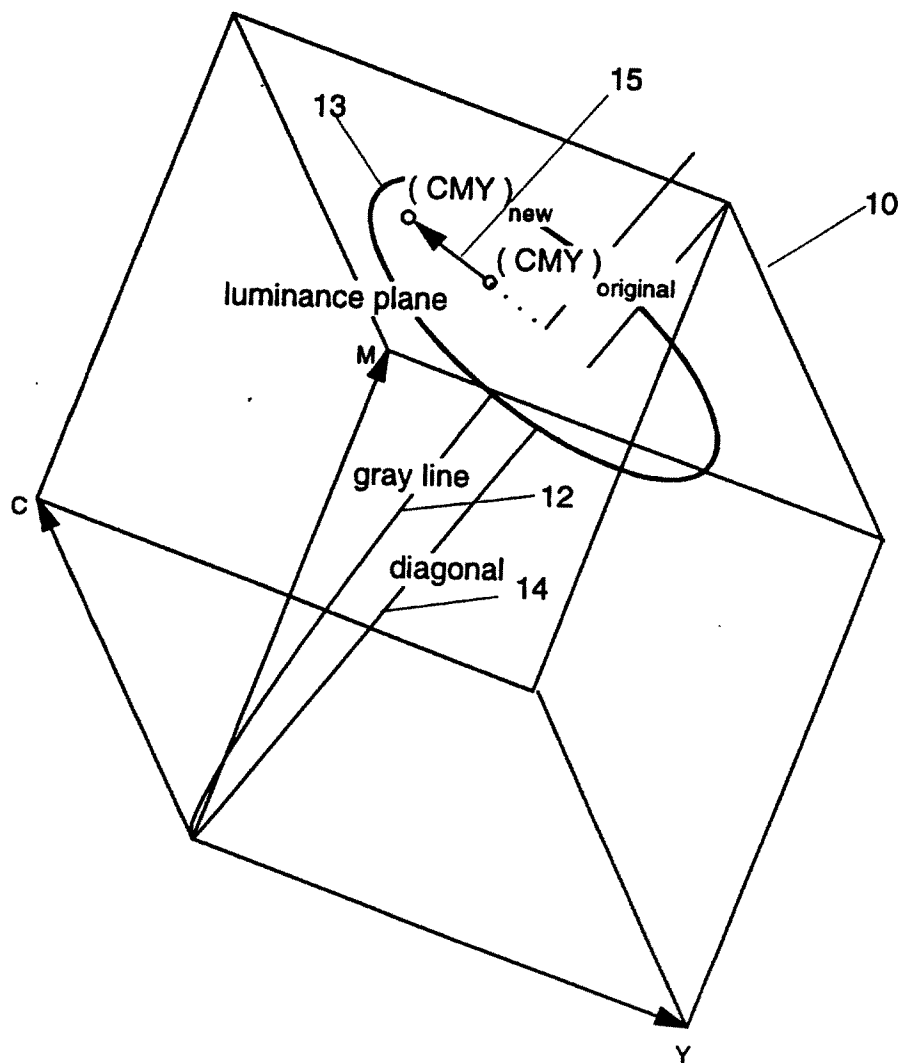$(CMY)_{original} \longrightarrow$ hue change $\longrightarrow (CMY)_{new}$

Hue change in CMY color space

Fig. 2

$(CMY)_{original}$ $\longrightarrow$ saturation change $\longrightarrow$ $(CMY)_{new}$

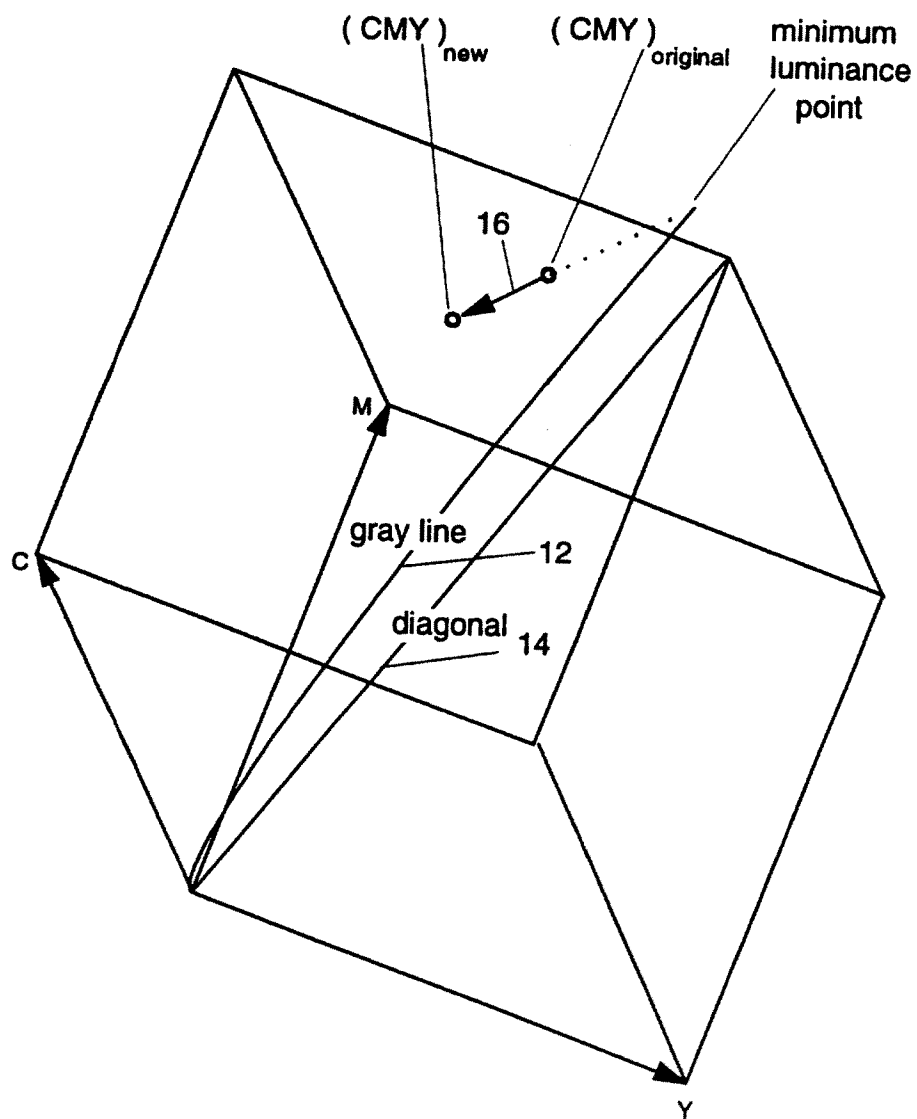Saturation change in CMY color space

Fig. 3

$(CMY)_{original}$ ⟶ luminance change ⟶ $(CMY)_{new}$

Luminance change in CMY color space

Fig. 4

INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

IPC 6   H04N1/60

   ding to International Patent Classification (IPC) or to both national classification and IPC

FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6   H04N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP,A,0 323 265 (CANON KK) 5 July 1989 see column 3, line 21 - column 4, line 18; claim 1; figure 1 ---	1
A	GB,A,2 182 822 (FUJI PHOTO FILM) 20 May 1987 see the whole document -----	1

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
15 May 1995	0 9. 06. 95

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+ 31-70) 340-2040, Tx. 31 651 epo nl, Fax (+ 31-70) 340-3016	Isa, S

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Information on patent family members

Patent document cited in search report	Publication date	Patent family member(s)		Publication date
EP-A-323265	05-07-89	JP-A-	1174455	11-07-89
		US-A-	5172223	15-12-92
GB-A-2182822	20-05-87	JP-A-	62111573	22-05-87
		DE-A-	3637995	21-05-87
		US-A-	5008742	16-04-91